ICECAPS: New Observations of Clouds, Atmosphere, and Precipitation at Summit, Greenland

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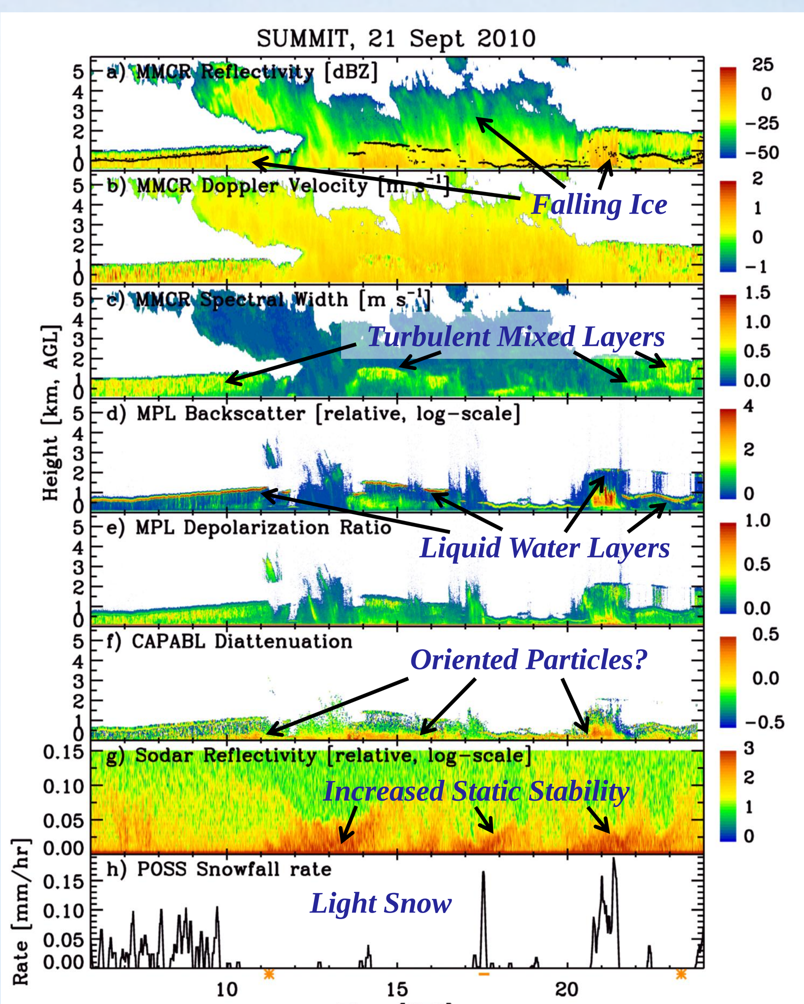
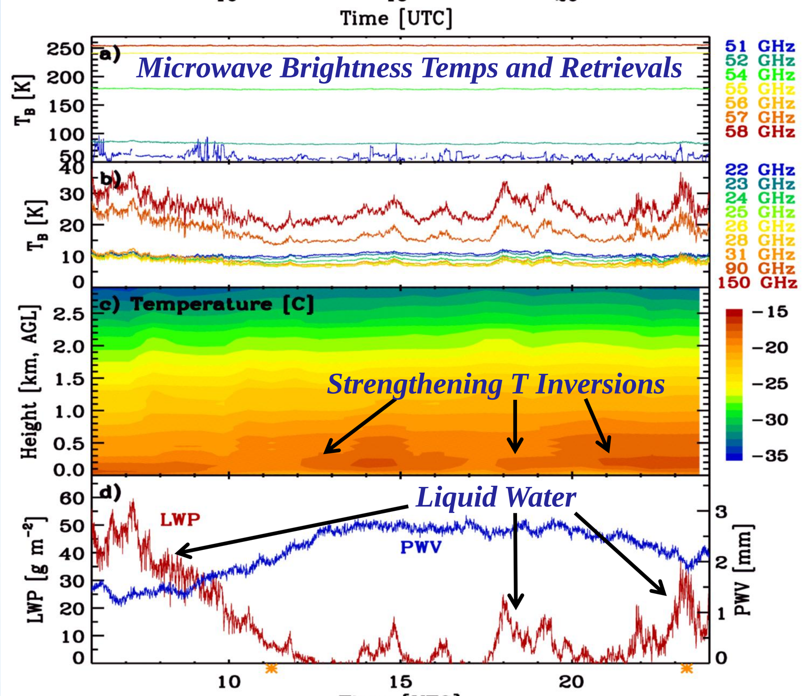
Instrument Suite Operating at Summit

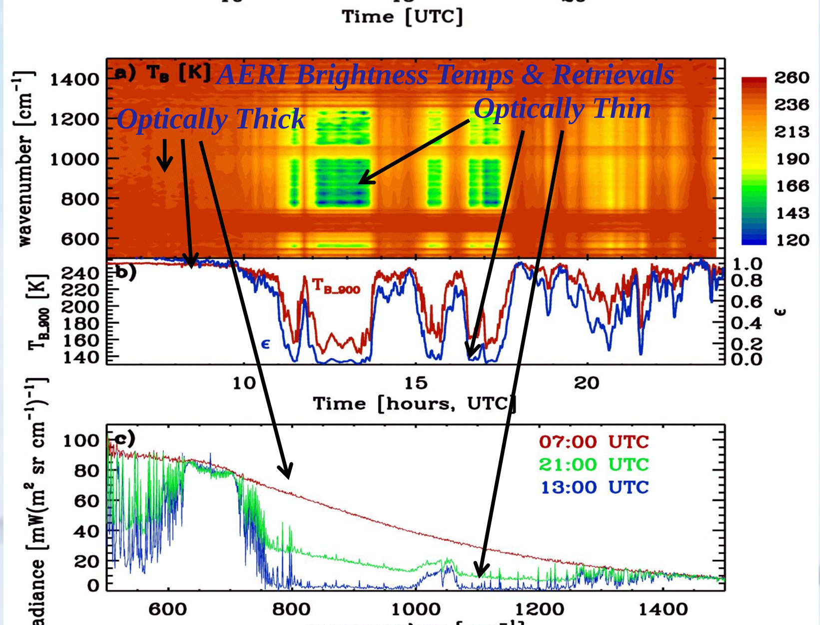
As part of the NSF Arctic Observing Network, the Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit (ICECAPS) project is providing a first look at detailed atmosphere and cloud properties over the central Greenland Ice Sheet. These observations are an important contribution towards the IASOA network of Arctic atmospheric observatories, and offer exciting new perspectives on this unique environment.

Instruments	Measurements	Geophysical Parameters
Millimeter Cloud Radar (MMCR)	35-GHz Doppler spectra and moments	Cloud phase, microphysics, dynamics
MicroPulse Lidar (MPL)	532 nm Backscatter, quasi-circular depol ratio	Cloud phase, microphysics, optics
Cloud-Aerosol Polarization & Backscatter Lidar (CAPABL)	523 nm Backscatter, linear depol radio, diattenuation	Cloud phase, microphysics, optics
Sonic Detection and Ranging System (SODAR)	2.1 kHz Reflectivity	Boundary layer depth
Precipitation Occurrence Sensor System (POSS)	10.5 GHz Reflectivity	Snowfall rate
Humidity and Temp. Profiling Radiometer (HATPRO)	Brightness temperatures @ 22-32 & 51-58 GHz	Liquid water path, precipitable water vapor, T
High Freq. Microwave Radiometer (MWR-HF)	Brightness temperatures @ 90 & 150 GHz	Liquid water path
Atmos. Emitted Radiance Interferometer (AERI)	IR Spectral Radiance, 530-3000 cm^{-1}	Cloud phase, microphysics, emissivity
Ceilometer	905 nm Backscatter	Cloud base height
Radiosondes	Temperature, RH, GPS position	Temperature, RH, Winds
Ice Particle Imaging Camera (IcePIC)	Digital photos	Crystal habit, riming

Complementary Perspectives







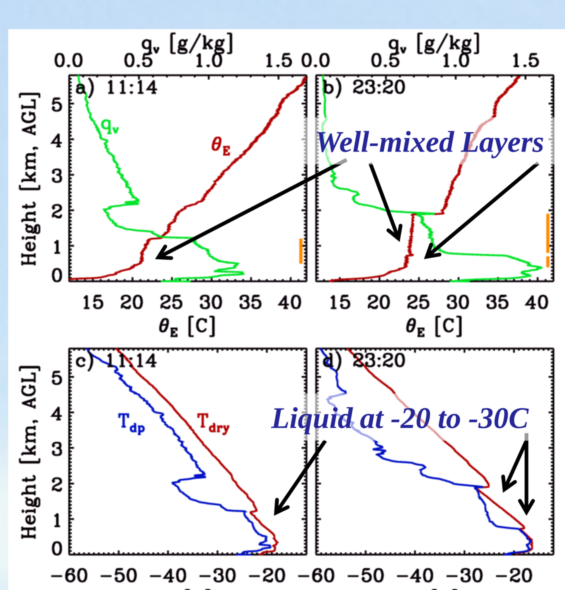
21 September 2010: Classic Arctic mixed-phase stratocumulus, glaciated intermittently by deeper layers of falling ice. This case illustrates the complementary abilities of the ICECAPS instruments

Cloud Ice: Falls from mixed-phase and deeper ice cloud layers. Identified by high radar reflectivity and velocity, low lidar backscatter, high lidar depol ratio, cold temperatures near top.

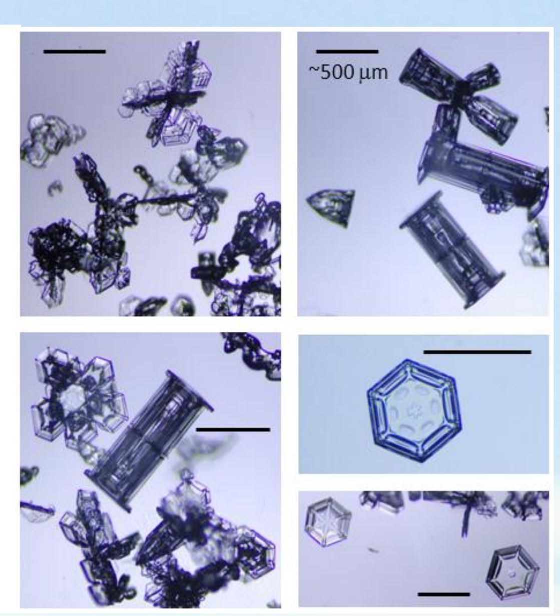
Precipitation: Intermittent, light snowfall. Identified by high radar reflectiviy and POSS snowfall rates. IcePIC pictures identify a variety of pristine crystal habits

Cloud Liquid: Multiple, stratiform layers with intermittent gaps. Identified by high lidar backscatter and low depol ratio, MWR-derived LWP > 0 g/m^2, high IR emissivity, radiosonde-measured saturated layers

Dynamics / Atmos. Structure: Mixed-layers associated with cloud liquid identified by wide radar spectrum width and constant radiosonde equivalent potential temperature. Sodar shows increased near-surface static stability when liquid cloud is gone (i.e., low IR emissivity), the surface cools, and T inversions strengthen.

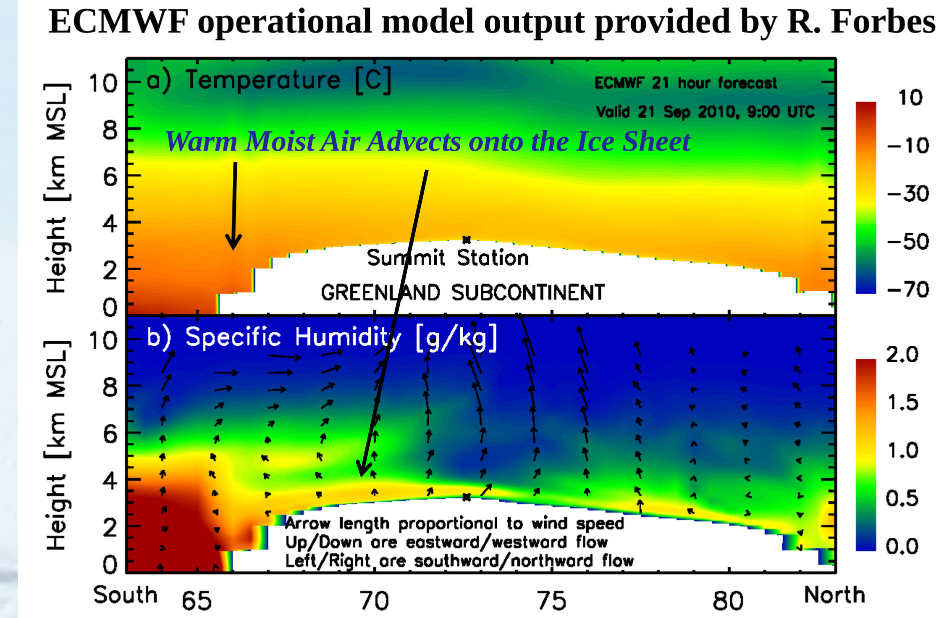


Radiosonde Profiles

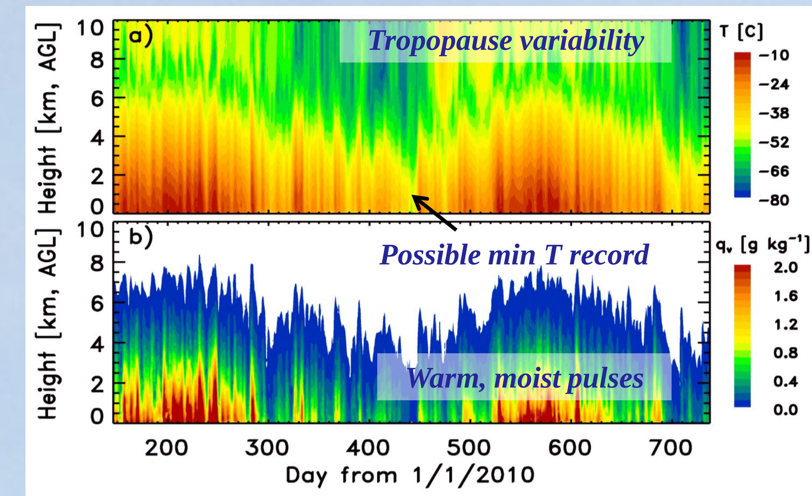


ICEPic photos

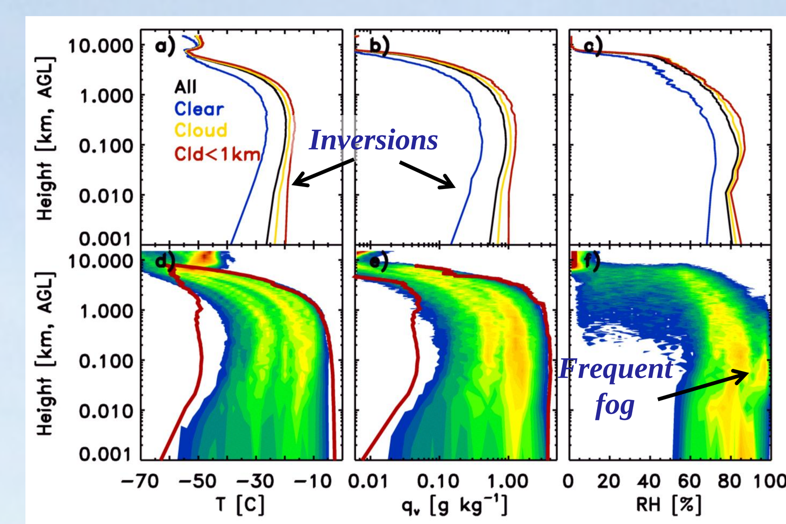
ECMWF operational model output provided by R. Forbes



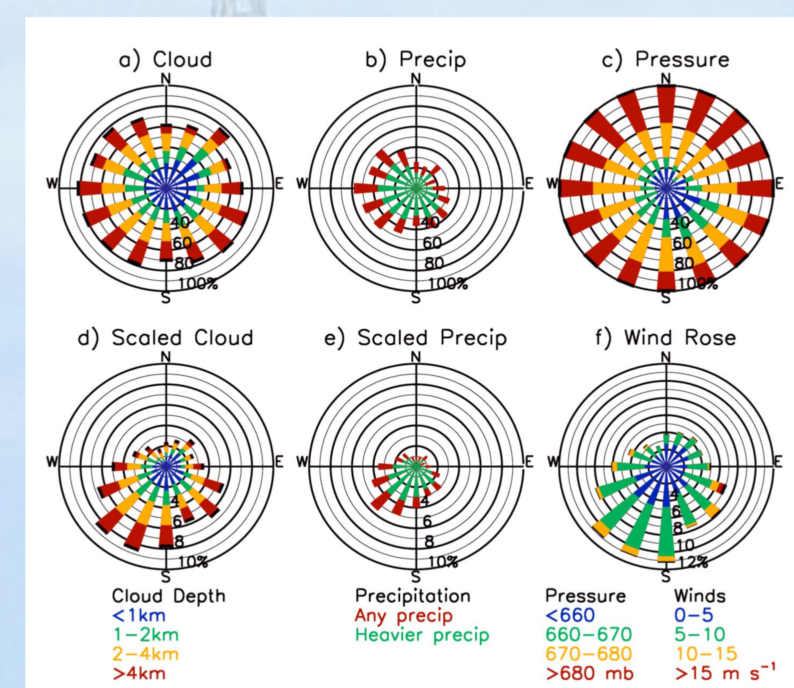
Atmospheric Structure



Radiosonde T and q from 5/2010 through 1/2012



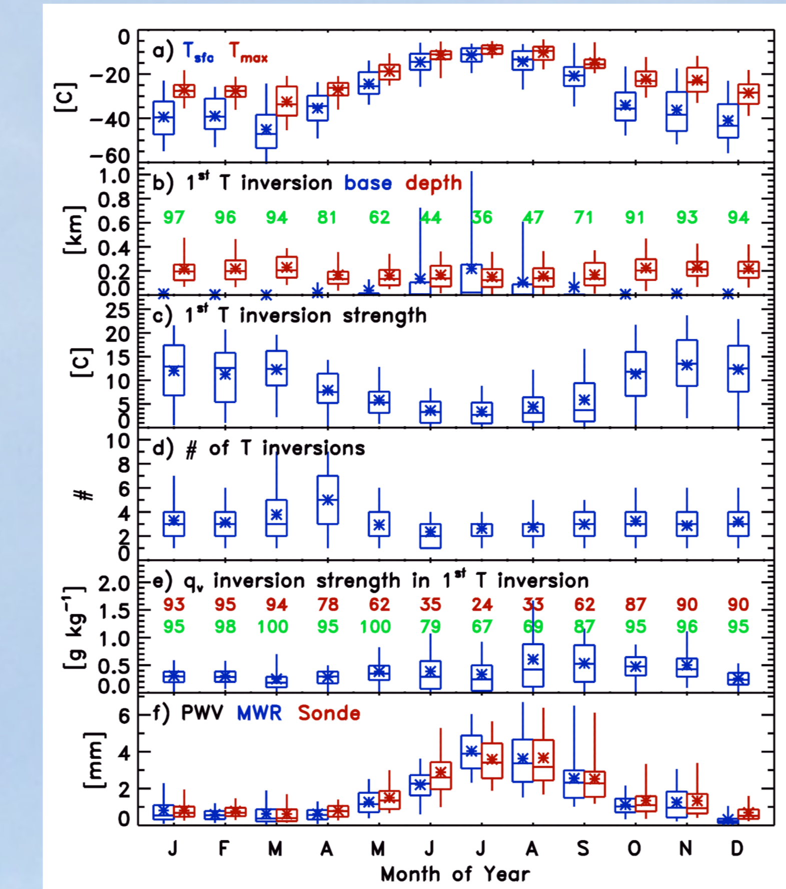
Means and PDFs of radiosonde T and q profiles from 5/2010 through 1/2012



(Top) Cloud/precip/pressure occurrence as a function of 10 m wind direction, and (bottom) scaled by the actual wind rose (f).

The ICECAPS twice-daily radiosonde program provides an unprecedented perspective on atmospheric structure above the central Greenland Ice Sheet.

- Periodic, warm, moist, and cloudy air masses advect onto the ice sheet. There is a clear distinction between air masses containing clouds and those without.
- A temperature inversion has occurred in every ICECAPS sounding except one.
- Strong, surface based inversions predominate through the winter season (>90% of the time). Moving towards summer, the low-level inversions are increasingly weaker and more often elevated off of the surface.
- Moisture inversions are typically associated with temperature inversions.
- Based on the annual cycle of temperature and atmospheric structure, "seasons" at Summit can be characterized as:
  - Summer: July and August
  - Autumn: September and part of October.
  - Winter: Most of October through mid-May
  - Spring: mid-May through June.

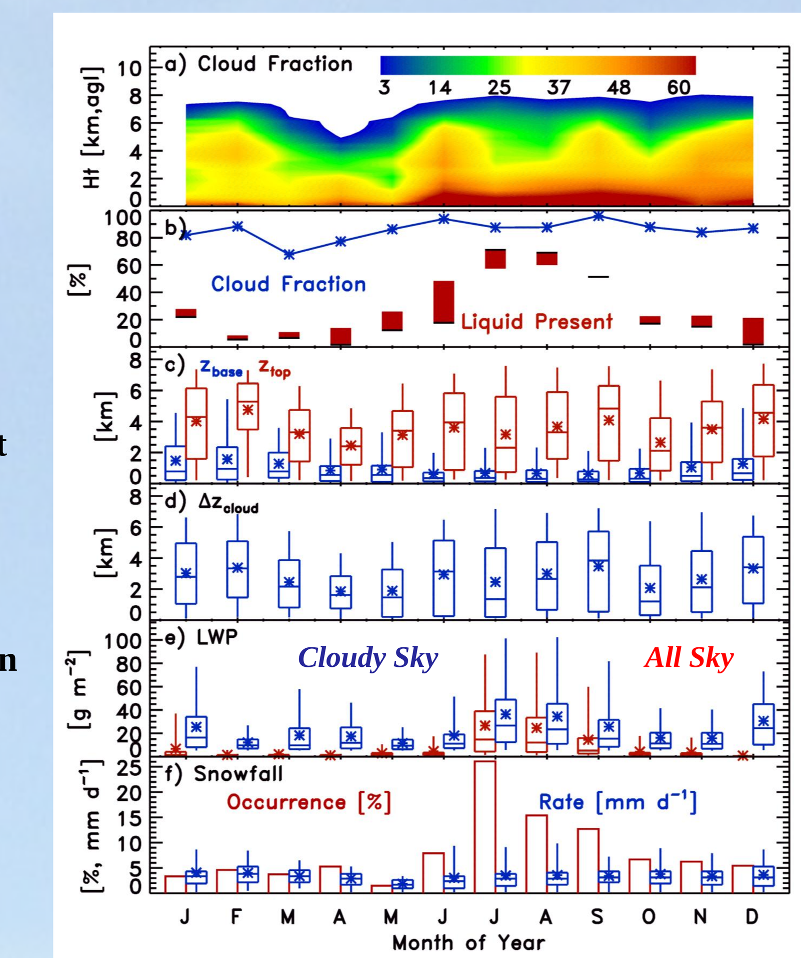


Monthly statistics characterizing the atmospheric state

Cloud Properties

ICECAPS measurements offer the first continuous, detailed characterization of cloud properties and structures over the central Greenland Ice Sheet.

- Clouds (here defined as hydrometeors in the atmosphere that are identified by at least one of the ICECAPS instruments) occur at least 65% of the time in each month with a late winter minimum.
- Cloud fraction decreases with increasing height.
- Supercooled liquid water is present year round, occurring <10% of the time in late winter but as much as 60% of the time in summer. The typical liquid water path (LWP) is small, reaching a maximum in summer.
- Snowfall rate is relatively consistent in all months of the year when snowfall occurs, but the occurrence fraction is much higher in the summer season.
- NE winds are least efficient at producing clouds and precipitation at Summit. W winds are most efficient for producing precipitation. Since winds as Summit are dominated by S-SW flow, most clouds and precipitation accompany winds from those directions.



Monthly statistics characterizing cloud properties

ICECAPS instruments installed in the Mobile Science Facility at Summit since May 2010